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Synthesis: Thresholds in conservation and management

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Abstract

This paper is a brief overview of some of the key issues which have emerged from the preceding set of papers on ecological thresholds. These include:

- Whether threshold relationships are common and widespread.
- The potential for large variations in the use and application of the threshold concept to lead to adverse conservation outcomes, particularly when overly simplistic levels of vegetation cover are specified by policy makers and land managers.
- The inherent multi-variate nature of landscape processes and responses of individual species and assemblages that creates variability in datasets. This may lead to a limited ability to make accurate predictions from threshold relationships, even when those relationships are highly statistically significant.

We believe that although the threshold concept is an appealing one and there is some empirical evidence to support it in some landscapes, it is not free of problems and a concerted research effort on the topic is needed. This is particularly important if it is to have value for robustly underpinning applied landscape management practices without unintentionally having negative impacts on rates of species loss or the loss of particular species.

Keywords: Thresholds; Landscape change; Habitat loss; Habitat fragmentation; Conservation

1. Introduction

Much has been written in recent times on the subject of ecological thresholds. Most of this has been of a theoretical nature (e.g. With and Crist, 1995; Pearson et al., 1996; With and King, 1999; reviewed by Huggett, this volume), although an increasing number of empirical studies are examining the concept, both for assemblages of taxa (e.g. Bennett and Ford, 1997; Drinnan, this volume; Lindenmayer et al., this volume; Radford et al., this volume) and for individual species (Jansson and Angelstam, 1999; van der Ree et al., 2003; Radford and Bennett, 2004). The papers in this special section (together with past literature) raise a number of issues associated with ecological thresholds that need to be addressed as part of better informed decision-making about whether the concept is appropriate to use in applied conservation and land management. In this synthesis, we highlight some of these issues, stressing caution in applying broad generalisations or threshold minimum values, and provide direction for future research. Our focus is on thresholds in landscape change (e.g., percent cover of native vegetation), as this has been the theme in many recent theoretical and empirical studies of relevance to biological conservation.

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2. General discussion

2.1. The generic applicability of the ecological thresholds concept

The papers in this volume demonstrate the variable results that can occur across studies of thresholds. For example, Radford et al. (this volume) and Drinnan (this volume) uncovered evidence for threshold responses in the bird and other assemblages they examined. Lindenmayer et al. (this volume) did not. Such a contrast in findings parallels other published work in the literature both for assemblages (e.g. Parker and Mac Nally, 2002) and for individual species (Jansson and Angelstam, 1999). This diversity of outcomes may be an artefact of the differences in statistical methods employed in searches for threshold responses. This suggests that future research apply the same or similar methods to several datasets. The extensive statistical analyses undertaken by Radford et al. (this volume) could serve as a benchmark for future studies.

Conversely, the variation in findings might be real and occur because of a range of inter-related factors including: (1) the assemblage or individual species in question; (2) the measure with which a threshold relationship is hypothesized to occur (e.g., extent of remaining native vegetation, patch isolation, etc.); (3) the timing and duration of landscape change (e.g., different threshold values may be identified for landscapes where habitat loss is relatively recent compared to landscapes where habitat loss occurred many decades previously); (4) the type, intensity, and extent of landscape change taking place and the associated processes potentially threatening the persistence of taxa (see Lindenmayer et al., this volume).

It seems reasonable to expect thresholds to occur for some individual species, particularly in relation to key environmental factors such as temperature, light and rainfall that are primary drivers of patterns of distribution and abundance (Woodward, 1987; Gaston and Spicer, 2004). Thresholds for assemblages may be more problematic because they require commonality of a trait or set of traits (e.g., home range/territory size; reproductive capacity; small population size dynamics) among a suite of species for them to occur. A preliminary exploration of threshold risks and commonality of traits might include a simple cross-tabulation and enumeration of the life history attributes of the taxa that comprise particular assemblages in a given area. That is, what common trait(s) do species share that may lead to a threshold response being identified for the assemblage? Identifying such traits is a major challenge for future research. We hypothesize that habitat cover thresholds identified for some assemblages will be related to the dynamics of small populations, whereby population size declines with habitat loss until many species exist as small populations each with a similar probability of extinction. Hence, when habitat cover breaches a given threshold, a substantial number of species are lost from the landscape because each existed as a relatively small population and shared a comparable susceptibility to extinction.

Irrespective of the underlying causes of the variation in outcomes of threshold analyses, it appears to us that a key issue is to determine how generic and widespread threshold relationships really are. This is critical given the increasing acceptance (appropriate or otherwise) of the threshold concept by policy makers and land managers (see below).

2.2. Variability in landscape processes and species responses

Many studies have demonstrated that the distribution and abundance of all species is influenced by factors at multiple spatial and temporal scales (e.g. Forman, 1964; Diamond, 1973). In altered landscapes, multiple interacting processes will have important effects on the responses of individual species, and will vary across species. For example, in some modified Australian landscapes, the interactive effects of aggressive behaviour of birds such as the Noisy Miner (*Manorina melanocephala*) vary with the extent of understorey vegetation, the size of patches of remnant woodland, and the body size of other birds (see Grey et al., 1997; Piper and Catterall, 2003). The impacts of an array of factors operating at different scales on species responses will add considerable variability to the relationships between a given species or assemblage and any single measured attribute of a landscape (e.g., % cover of native vegetation) (see Lindenmayer et al., this volume). Such variability will limit the predictive ability of these relationships, even in cases where there is a highly significant statistical relationship between a response variable and an explanatory variable. Limited predictive ability means, in turn, that considerable caution will be needed in applying threshold relationships (and other sorts of relationships) as part of on-ground resource management.

2.3. Other issues – scale, multi-thresholds, uni-directional thresholds

One of the potential problems in threshold studies to date is that they have been focussed at a single spatial scale. However, where thresholds exist, it is possible that different thresholds may manifest at different spatial scales. This is a key issue because habitat loss and habitat fragmentation are multi-scale problems (Lindenmayer and Franklin, 2002). This was neatly elucidated by Angelstam (1996) for forests, but the problem is equally apt for other ecosystems. First, at a landscape-scale, there can be a direct loss of habitat per se. Second, within 'intact' habitat remnants, formerly continuous areas of distinct vegetation types or successional stages (e.g., old-growth forest stands) can be lost or become fragmented. Finally, structural and floristic elements can be lost within given vegetation types (Angelstam, 1996).

Theoretical work on thresholds, particularly simulation studies, suggests the occurrence of a single and uni-directional ecological threshold in a system (Andrén, 1994; With and Crist, 1995). Further exploration of the concept would be useful with respect to the possible existence of two or more critical change points. It also would be valuable to explore theoretically and empirically the directionality of the concept, both to determine if thresholds work in reverse for aggregate measures such as species richness. That is, if rapid species gain occurs in response to habitat expansion efforts such as broad scale restoration programs.

2.4. Ecological thresholds as a potentially dangerous minimalist approach

The thresholds concept is gaining increasing credibility among policy makers and land managers, particularly for setting benchmarks for levels of landscape cover (McAlpine et al., 2002). For example, clearing of native vegetation cover to levels of 30% of original extent or restoring vegetation to 10–30% of the area of a farm or landscape is potentially dangerous for several reasons.

First, the diversity of results from the studies reported in this volume (and those published previously) indicates that the evidence to underpin a given nominal value is not yet convincing (e.g., see Parker and Mac Nally, 2002). Second, the use of threshold values as described above appears to be based on a mis-interpretation of the original threshold theory. Habitat loss in landscapes can lead to species loss (Fahrig, 2003). Threshold theory suggests that species losses will be faster below a specified threshold level. However, species losses and population declines will still take place *above* this level. This led Mönkkönen and Ruenanen (1999) to suggest that hypothesized 10–30% threshold levels in habitat cover will be an underestimate for many groups and that *some species could be lost above* particular 'threshold' cover levels, simply as a function of habitat loss per se. Indeed, some threshold levels identify the point where a substantial number of species are lost from the landscape, whereas the focus should be more on the point where most species are able to maintain viable populations for many generations.

The third reason we are concerned with uncritical applications of the threshold concept to land management is that for most landscapes, patterns of habitat loss are not random, and do not result in a given level of habitat cover of uniform quality. Rather, habitat loss is a non-random process driven by human land use practices. Vegetation remnants are not therefore representative of the pre-fragmentation landscape (Saunders et al., 1987; Norton et al., 1995). The most productive parts of a landscape are almost always those modified first (Woolley and Kirkpatrick, 1999; Scott et al., 2001). In these cases, the response of some individual taxa (and the number of species persisting) will be affected strongly by the *quality* of what remains as well as how much remains. Hence, percent habitat cover that needs to be maintained to support most species will vary depending on the quality of the habitat. Indeed, one could envision an interactive relationship between thresholds in habitat quantity and quality.

We recognize that for a range of reasons, policy makers and land managers will often seek simple solutions to complex landscape management problems. However, it must be acknowledged that often arbitrarily chosen "threshold levels" for measures such as total vegetation cover may in fact not stem losses of some species from landscapes. This further emphasizes the urgent need for more work to test the generic validity of the threshold concept for use in directing policies for applied landscape management, native vegetation conservation, and landscape restoration efforts.

2.5. Variations in the interpretation of the ecological thresholds concept

Like many issues and concepts in conservation biology, the ecological thresholds concept has been taken to mean different things by different people (see Huggett, this volume). This is true for both conservation biologists and policy makers. The mis-interpretation of the theory in its application to maintain native vegetation cover levels at 10–30% is an example; a problem that could have major negative implications for conservation. Clearly, there is a need for a more consistent use and application of the concept and the associated terminology.

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